# Microplastics Removal and Accumulation in Southern California Biofilters

## Élimination et accumulation des microplastiques dans les biofiltres du sud de la Californie

Elizabeth Fassman-Beck, Ph.D., Danhui Xin, Ph.D.

Southern California Coastal Water Research Project
elizabethfb@sccwrp.org
danhuix@sccwrp.org

## RÉSUMÉ

Le ruissellement des eaux pluviales s'avère être une source importante de microplastiques (MP) dans les cours d'eau en aval. Afin de répondre aux questions de gestion relatives à ce contaminant émergent, nous avons cherché à quantifier l'efficacité des dispositifs de gestion des eaux pluviales par biofiltration (ou biorétention) pour réduire la présence de MP, et à évaluer si les spécifications des matériaux filtrants sont adaptées à la capture des différentes tailles de MP présentes dans le ruissellement. Nous avons mené une étude de terrain pour mesurer les concentrations moyennes événementielles (CME) et les distributions de taille (de 20 µm à > 500 µm) des MP dans les eaux d'entrée et de sortie, et quantifier leur accumulation dans les matériaux filtrants en fonction de la distribution de la taille des pores et des particules de ces matériaux. Sur 18 événements pluvieux observés sur 7 biofiltres, la réduction médiane des CME de MP était de 72 %, avec une réduction variant de 68 à 100 % selon les fractions de taille. La filtration physique (c'est-à-dire le tamisage) a été identifiée comme le principal mécanisme d'élimination des MP dans les biofiltres, comme en témoigne la forte corrélation entre l'élimination des MP et celle de toutes les particules restantes après extraction. Les matériaux présentant une proportion plus importante de pores inférieurs à 20 µm accumulaient davantage de MP. La forte concordance entre la présence et l'élimination des particules sur une large gamme de concentrations indique que le nombre total de particules peut servir d'indicateur pratique pour estimer la présence de MP et l'efficacité des dispositifs de gestion des eaux pluviales en milieu urbain.

## ABSTRACT

Stormwater runoff is emerging as a significant contributor of microplastics (MP) to downstream waterways. To begin to answer management questions on this emerging contaminant, we sought to quantify the extent to which existing biofilter (a.k.a. bioretention) stormwater control measures reduce MP, and to evaluate whether engineered media specifications are adequate to capture the range of MP sizes occurring in runoff. We conducted a field monitoring study to measure MP event mean concentrations (EMCs) and size distributions (20 µm to >500 µm) in influent and effluent, and quantify accumulation in engineered media with respect to the media's pore and particle size distributions. Across 18 storm events collected from7 biofilters, median MP EMC reduction was 72%, EMC reduction ranged from 68–100% for different size fractions. Physical filtration (i.e., straining) was identified as the dominant removal mechanism for MPs in biofilters, supported by the close correspondence between the removal of MPs and all particles remaining after extraction. Media with a larger proportion of pores < 20 µm accumulated more MP. The strong alignment in occurrence and removal across a wide concentration range indicates that all particle counts may serve as a practical surrogate for estimating MP occurrence and BMP treatment in urban runoff.

## KEYWORDS

bioretention, emerging contaminants, microplastics, runoff, treatment

# 1 INTRODUCTION

Microplastics (MP), defined as plastic particles <5 mm long[1], have emerged as a contaminant of concern in stormwater. MPs occur over a range of particle sizes, which may influence their fate and transport in the environment, their behavior during treatment processes, and ultimately their downstream ecological and human health impacts[2,3]. Urban runoff is now recognized as a major pathway for MPs to enter the ocean, often contributing higher loads than wastewater discharges due to their widespread occurrence and the diffuse nature of non-point source inputs[4–8]. MPs are not currently regulated in stormwater in the USA, therefore neither treatment objectives, nor design criteria, nor operational guidance has been developed for their management using BMPs.

The literature to date reports measured performance from only three distinct biofilters, with event-based MP removal reported at 80% to >99%.[7,10-14]. The California Statewide Microplastics' Strategy[14] seeks to promote existing activités (including infrastructure implementation) that reduce MP transport into the ocean, thus we sought to confirm findings on a broader scale.

The primary technical objective of this study is to quantify the extent to which existing southern California biofiltration BMPs reduce MP concentrations in urban runoff, and evaluate treatment across five size fractions (20 µm to >500 µm) prior to downstream discharge. A secondary objective is to confirm that physical filtration (namely straining) is the dominant mechanism(s) of MP removal, and develop design recommendations to promote MP capture.

# 2 METHODS

## 2.1 Site descriptions

Stormwater runoff sampling was conducted at seven biofilters in the Southern California Stormwater Monitoring Coalition Regional BMP Monitoring Network[15]. All BMPs were designed to capture runoff from the 85th-percentile water quality design storm and are partial-capture biofilters. These are lined systems that intercept wet-weather runoff and discharge treated runoff through underdrains to the MS4 or a downstream waterway. All of the monitored biofilters were constructed between 2018 and 2020. Drainage areas include multi-lane roads, parking lots, and park/open space, with hydraulic loading rates to the biofilters of 7-85. One biofilter had a media depth of 46 cm, five were 61 cm deep, and one was 94 cm deep. All biofilters are located within the jurisdiction of the SMC (https://socalsmc.org/). Specific biofilter names and locations are kept anonymous, as per SMC practice.

## 2.2 Sampling

The semi-arid climate of southern California offers typically fewer than 10 storms events over the wet season of Oct-April (there is rarely rain at other times of year), thus the SMC BMP Regional Monitoring Network adopts study designs that samples a few storms from multiple biofilters each season to support robust data collection in limited timeframe. All SMC agencies follow sampling procedures outlined in the Work Plan[15] and Quality Assurance Project Plan. Paired influent-effluent runoff samples from BMPs were collected between February 2024 and April 2025. For each event, a 1–8 L flow-weighted composite (influent or effluent) sample was obtained either directly from an autosampler or by generating a composite manually using the post-processing method applied to discrete autosampler bottles[16]. A composite media sample was collected once from each of four of the biofilters dry weather. An extensive array of blanks were collected during every stage of sample collection and analysis to ensure data quality.

## 2.3 Laboratory analysis

Standardized methods for analyzing MPs in stormwater runoff have not yet been established in the literature. SCCWRP used extensive in-house expertise to adapt the drinking water analysis method adopted by the State of California[1] for runoff analysis. Briefly, runoff flow-weighted composite samples and media composite samples were size-fractioned using sieves (20 µm, 63 µm, 125 µm, 355 µm, and 500 µm). Potential MPs were extracted from each size-fraction subsample using an acid/alkaline digestion method[17]. Extracted particles were counted using a LAXO microscope equipped with a Z203P digital camera (Mill Creek, Washington). Finally, MPs were identified by Fourier-transform infrared spectroscopy (FTIR) using a Nicolet iN10 MX Infrared Imaging Microscope (Thermo Scientific, Madison, WI), following the procedures of De Frond et al. (2023). Analysis of flow-weighted composite samples yields event mean concentrations (EMCs).

Media samples were also analyzed for particle and pore-size distributions.

## 3 RESULTS

Across seven biofilters, 18 storm events were sampled, with individual BMPs sampled for 1–8 events. Rainfall depth for sampled events ranged 0.6-8.2 cm. The monitored events covered a wide range of operating conditions compared to the design storm sizes (1.2–2.2 cm), with approximately 40% of the monitored storms falling within ±30% of design storm depth.

Untreated, influent EMCs measured in runoff ranged from dozens to 6850 particle/L (Figure 1a). Treated effluent concentrations were substantially lower and exhibited less variability, as indicated by the narrower interquartile range (IQR), suggesting that biofilters effectively reduce MP concentrations at the site scale and produce comparatively consistent effluent quality. The median treatment efficiency across all events was 72%, indicating overall substantial reduction in MP EMCs. Almost all MPs were removed in two events; the effluent EMCs in these events were 3 particle/L and 15 particle/L. One event in BMP 9-1 exported MP; this event was statistically identified as an outlier for the dataset.

Few influences on performance or effluent quality were identified. Neither the ratio of rainfall depth to design depth nor media depth were correlated to performance, although the biofilter with the shallowest media depth did exhibit the greatest variability in effluent EMCs.

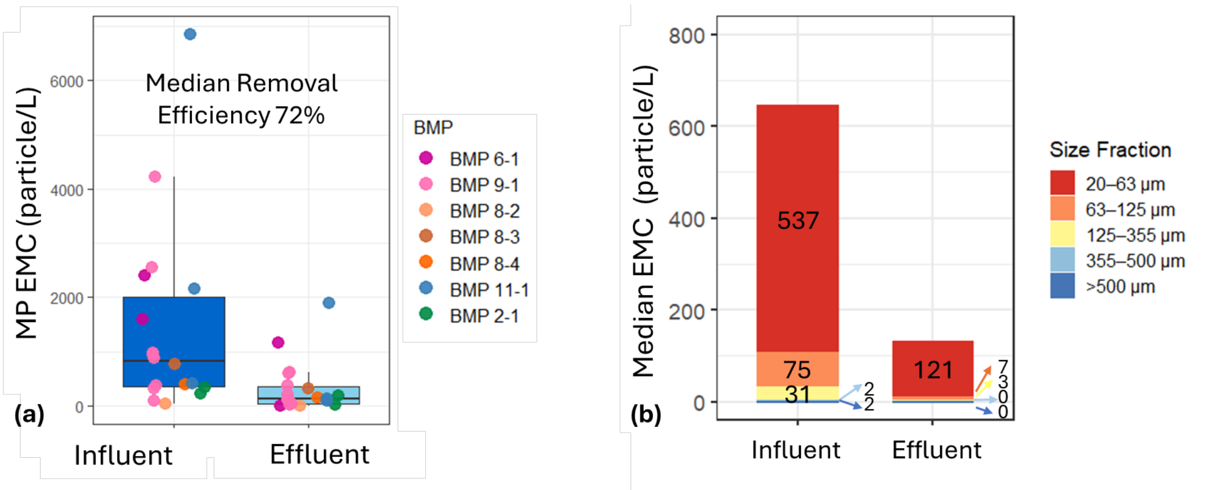


Figure 1. (a) MP EMCs in the influent and effluent, and median event-based removal efficiency. Individual points are overlaid and color-coded by BMP identifier ; (b) Median EMCs by size fraction

The smallest size fraction evaluated (20–63 µm) dominated influent and effluent EMCs (Figure 1b). Regardless, MPs in this size fraction still showed a substantial decrease following biofilter treatment — the median concentration dropped to 121 particle/L in the effluent, corresponding to a treatment efficiency of 68% (IQR: 39–92) for this size fraction. Although this efficiency was lower than that of larger size fractions (all others were above 85%), overall treatment efficiency across all measured sizes remained high.

Media analysis revealed that showed MPs are predominantly captured by straining within fine pores of the media, similar to other particles remaining after extraction. This offers practical evidence that stormwater treatment practices designed to remove particulate contaminants are likely highly effective for MPs. Biofilters containing greater proportions of <20 µm pores in the media showed better MP accumulation and capture during storms. Because media pore size distribution is a labor-intensive measurement and uncommon in practice, measuring media particle size distribution is strongly recommended by current design guidance. An index derived from particle size distribution, the curvature coefficient [$(D_{30})^2/(D_{10} x D_{60})$], strongly correlated with the proportion of <20 µm pores and MP retention in the media sampled. The curvature index offers a more practical indicator for designing for successful MP capture. Modifying BMP design instructions must consider potential impacts to other treatment or drainage functions.

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